Recommended Features for Digital Reporting Systems to Support Emissions Disclosures for Small and Medium-Sized Enterprises

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Abstract. Sustainability reporting has evolved from a voluntary practice into a regulatory obligation, particularly within the European Union, where the Corporate Sustainability Reporting Directive (CSRD) mandates extensive Environmental, Social, and Governance (ESG) disclosures. Among its most demanding components is greenhouse gas (GHG) emissions disclosure, which poses significant challenges, particularly for small and medium-sized enterprises (SMEs) lacking the technical infrastructure, expertise, and resources to accurately collect, measure, and report the required data. Despite the urgency of CSRD compliance, there is limited academic research on how SMEs adopt or struggle with digitally enabled solutions to meet their emissions reporting requirements. To address this gap, this study investigates key digital and workflow-related challenges SMEs face in collecting and reporting emissions data in preparation for compliance. Adopting a multi-method approach, the study begins with a document analysis of white papers, policy reports, and CSRD standards to establish normative expectations for emissions reporting. Concurrently, a qualitative case study involving semi-structured interviews with professionals from SMEs takes place to identify recurring obstacles and practices. Finally, through a gap analysis between regulatory expectations and actual SME practices, the study identifies key barriers to CSRD compliance and offers recommendations for digital reporting system features that facilitate verifiable, consistent, and machine-readable emissions reporting. In doing so, the study contributes to an emergent ESG literature by offering insights into SME emissions reporting practices. It is also intended to inform software vendors aiming to support SMEs in navigating the technology-driven CSRD compliance landscape.

Keywords: CSRD Compliance, Emissions Reporting, Digital Reporting Systems, SMEs

1 Introduction

Sustainability reporting refers to the process through which organizations measure, disclose, and take accountability for their performance related to sustainable development goals, addressing the needs of both internal and external stakeholders for transparency [25]. Initially embraced by a small number of forward-thinking organizations, sustainability reporting was primarily driven by reputational concerns and stakeholder engagement rather than regulatory mandates [4]. However, in today's business environment,

shaped by complex social and environmental challenges such as recurring public health crises and climate change-induced natural disasters [32,33], companies are under growing pressure to report not only their financial performance but also the broader environmental, social, and governance (ESG) impacts of their activities [24].

A key regulatory development reinforcing this increasing pressure on companies to adopt sustainability reporting practices is the European Union's Corporate Sustainability Reporting Directive (CSRD) [16]. Designed to guide and compel firms toward more transparent and standardized ESG disclosures, the CSRD mandates detailed, auditable sustainability reporting aligned with broader EU climate and social goals [16]. While initially targeting large organizations, those with more than 250 employees and an annual turnover exceeding €50 million [15], its scope is set to progressively expand, ultimately encompassing small and medium-sized enterprises (SMEs).

Even though the legal language and regulatory intricacies of the CSRD are intended to be clarified through the European Sustainability Reporting Standards (ESRS)[1], its practical implementation remains fraught with challenges. Organizations must navigate several obstacles, including the need to collect granular, disaggregated ESG data across their entire value chain [11], the limited availability and reliability of internal ESG data [18], difficulties in reconciling CSRD requirements with existing financial reporting frameworks, and the methodological complexity involved in conducting double materiality[2] assessments [8]. Among the ESG dimensions mandated by the CSRD, emissions reporting, widely regarded as the most representative indicator of an organization's environmental impact, has proven particularly challenging. Scope 3 emissions, in particular, refer to indirect greenhouse gas (GHG) emissions that occur throughout a company's value chain and often represent the largest portion of its total carbon footprint [30]. Accurately accounting for these emissions, is especially difficult, as it relies on data from upstream suppliers who often lack standardized reporting practices and transparency [8]. These difficulties are compounded by fragmented data governance structures and poor interoperability across data collection and reporting systems, which hinder traceability and undermine data quality across supply chains.

That said, large corporations are often better positioned to manage emissions data reporting challenges, drawing on institutional knowledge and support from dedicated ESG teams [7]. Contrastingly, SMEs frequently lack the resources, expertise, and technological infrastructure necessary to comply with the data-intensive demands specific to emissions reporting under the CSRD [19]. These limitations are further compounded by the absence of automated reporting systems for tracking and reporting emissions data and a continued reliance on manual data collection from diverse, decentralized sources across the value chain [19]. Additionally, the financial burden associated with compliance, including the acquisition cost of ESG-management software, external audits, and

[1] The ESRS consist of 12 standards covering all ESG dimensions required by the CSRD [9,4]. The number and complexity of these standards, requiring the establishment of extensive data collection and management processes, make CSRD compliance particularly challenging for resource-constrained SMEs [11,18,8,29].

[2] Double materiality refers to the obligation to assess both a company's impact on the environment and society (inside-out perspective) and the impact of environmental and social changes on its financial performance (outside-in perspective) [9,6].

consultancy services, can be prohibitively high for SMEs, creating a substantial barrier to meeting the emissions reporting requirements mandated by the CSRD [29].

In this regard, the present study aims to gain a deeper understanding of how SMEs navigate the complex data collection and reporting challenges of CSRD implementation, particularly with respect to GHG emissions reporting. It also seeks to derive practical insights for eliciting digital reporting system features that enable consistent, reliable, and scalable sustainability disclosures. Accordingly, this study is guided by the following research questions: *"What are the key barriers SMEs encounter in aligning their emissions reporting practices with CSRD regulatory expectations?"* and *"What recommendations for digital reporting system features can be derived from these regulatory expectations and practical challenges?"*.

In the context of this study, the term *'digital reporting systems'* or, more succinctly, *'systems'*, aligns with the definition provided by Pizzi et al. [26]. This refers to configurable technological infrastructures, including software platforms, application programming interfaces (APIs), emissions calculators, and data validation tools, designed to support data integration, enhance data quality, and automate sustainability reporting in alignment with CSRD requirements. However, the aim of this study is not to prescribe exact technical specifications or architectures for such systems. Instead, it focuses on identifying features that should inform their design, drawing from both regulatory mandates and the practical challenges SMEs encounter in real-world implementation, particularly in the context of emissions reporting. Developing such systems in-house requires substantial technical expertise and resources, often beyond the reach of many SMEs [29]. Therefore, this study aims to derive a set of *feature recommendations* to guide software vendors and solution providers in designing or adapting off-the-shelf solutions that can be customized to meet SME needs. Drawing on best practices[3], the recommendations outline essential system features and their rationale, providing practical guidance for translating compliance requirements into system capabilities.

To address the research questions, this study adopts a multi-method approach [35]. First, a document analysis is conducted to extract normative requirements for emissions reporting, as prescribed in policy documents detailing CSRD implementation. This serves as a desk-based method for establishing a reference baseline for regulatory expectations. Next, a qualitative case study [37] is carried out involving semi-structured interviews with professionals from a diverse set of SMEs currently preparing for CSRD compliance. The interviews explore tools, processes, and organizational constraints shaping emissions data collection and reporting. Finally, insights from both steps are integrated into a comparative gap analysis that contrasts current organizational practices with CSRD regulatory demands. This analysis informs the development of targeted feature recommendations to help bridge the gap between compliance expectations and practical implementation realities. In doing so, this study aims to contribute to the growing body of empirical research on sustainability-oriented system design by offering actionable insights tailored to key stakeholder groups such as: system designers and vendors of digital reporting solutions, policymakers involved in refining CSRD-related implementation with consideration of technological factors, and SMEs seeking to enhance their operational preparedness for emissions-related compliance.

[3] The format of these recommendations follows the guidance of ISO/IEC/IEEE 29148:2018.

Section 2 outlines the research methodology. Section 3 presents the key findings on the normative expectations SMEs are required to fulfill under the CSRD, outlines the challenges they face in emissions reporting, and introduces the corresponding feature recommendations. Sections 4 and 5 discuss limitations and conclude the paper.

2 Research Methodology

2.1 Research Approach

To investigate how SMEs manage the data-intensive emissions reporting obligations under the CSRD, and to identify system design implications that can support compliance, we conducted an exploratory study [2]. Given the limited normative and empirical understanding in this area, the study adopted a multi-method approach [35] to bridge regulatory expectations with the practical realities of emissions reporting in SME contexts. This approach was chosen for its ability to generate rich insights into complex, context-sensitive topics and to integrate diverse methods of knowledge acquisition and data extraction [22]. Since we were interested in integrating theoretical insights with empirical data in real-time, an abductive research approach (i.e., a combination of deduction and induction [28]) was adopted. To be specific, our study began with a document analysis of white papers, policy reports, and institutional implementation guidelines, all related to the CSRD, to deductively extract high-level, emissions reporting normative expectations. This analysis served to establish a baseline for understanding essential system-related demands for achieving CSRD compliance. Concurrently, we conducted a qualitative case study focused on multiple SMEs preparing for CSRD implementation. Drawing on semi-structured interviews with professionals involved in sustainability reporting and compliance, the case study explored how these organizations navigate emissions data challenges within their specific organizational contexts. The interviews were thematically analyzed to inductively identify key challenges, practices, and perceptions related to emissions data collection and reporting. Finally, by comparing regulatory expectations with the challenges faced by SMEs, a nuanced understanding of the implementation gap was established to inform practical recommendations for key features of digital systems that support CSRD-compliant emissions reporting. Below, we outline the research strategies employed.

2.2 Document Analysis

Given the limited peer-reviewed research on the practical implementation of the CSRD, this study primarily relies on analyzing documents such as white papers, policy briefs, consultancy reports, and official publications from European Union (EU) institutions. This analysis served two purposes: *First*, to develop an understanding of the broader CSRD framework, with particular emphasis on the ESRS[4], the standards specifying the reporting demands for companies to comply with the CSRD. Our focus was particularly on ESRS 1 and ESRS 2, which cover general ESG disclosure requirements and business conduct, as these form the core structure of the directive. In addition, ESRS

[4] For an overview of all ESRS standards, see: https://shorturl.at/knxDZ

E1 was considered to capture climate-related disclosures, especially GHG emissions, given its centrality to environmental reporting and its alignment with the study's focus on SME emissions reporting challenges. *Second*, we sought to identify documents deriving emissions reporting requirements and implications for SMEs. To ensure relevance, we applied a set of criteria in the document selection process. Documents were required to originate from authoritative bodies such as EU institutions, leading consultancy firms with demonstrable expertise in sustainability and regulatory compliance, and think tanks with influence on European environmental policymaking. The initial document search was conducted across publicly accessible repositories, including official EU websites and consultancy publication portals, with priority given to documents published within the last five years to capture the most current regulatory developments. Additionally, sources were required to address CSRD obligations or implications for SMEs, with a particular focus on emissions data collection and reporting practices. Although this narrowed the number of documents included, it helped us prioritize those offering actionable insights for SMEs. At this stage, we did not aim to extract system feature specifications from the documents; rather, our goal was to identify those defining regulatory expectations and operational requirements to inform potential feature development later on. This approach allowed us to build a practical, experienced-based understanding of the CSRD-along with the fundamentals of the ESRS-and their regulatory implications on SMEs. A list of all included documents, with their origin, type, and reason for inclusion in this study, is provided in Appendix A[5].

Next, narrative synthesis [20] was employed to review, integrate, and present the findings of the retrieved documents in a cohesive manner. The process began with the extraction of key requirements, guidance, and recommendations from ESRS 1, ESRS 2, and ESRS E1, which were initially grouped into broad descriptive themes such as reporting procedures, emissions data requirements, and double materiality. These contributions were then synthesized into a coherent narrative, integrating findings across documents to provide a clear overview of the CSRD, its purpose, and its obligations for SMEs. Building on this synthesis, the descriptive themes were further refined into actionable normative expectations, capturing recurring trends and translating general guidance into specific obligations, such as robust Scope 3 emissions estimation and quantification, and integrated emissions reporting data management practices, among others. Throughout the process, the narrative was cross-checked against the original documents to ensure completeness, reflecting regulatory requirements while maintaining practical relevance for SMEs. The narrative summary, together with the refined normative expectations and their corresponding sources, is presented in Section 3.1.

2.3 Case Study

Case studies are particularly well-suited for exploring complex, real-world phenomena where contextual factors are deeply intertwined with organizational behaviors [37]. Accordingly, we employed a case study approach centered on the IT auditing division of an international advisory firm based in the Netherlands. This division plays an increasingly important role in assessing the integrity and reliability of sustainability-related

[5] The online Appendices can be found at: https://shorturl.at/aWy23

data as organizations begin aligning with the reporting expectations set by the CSRD. Through our engagement with this division, we first gained insight into the practical challenges of CSRD implementation, as observed in their advisory work. Drawing on their sectoral expertise and established client relationships, the division then facilitated access to a diverse portfolio of SME clients at various stages of preparing for CSRD compliance. Although these SMEs are not yet formally subject to the directive, they are already facing pressure to develop robust emissions reporting capabilities. Rather than focusing on individual sub-units or specific practices within the SMEs, this study considered each SME's overall approach to emissions data management. Accordingly, the unit of analysis was each individual SME operating in the European market, treated as a cohesive whole. This approach was meant to capture the broader organizational context, including structures, technologies, and regulatory interpretations, while avoiding fragmentation into departmental or team-level activities.

Data collection was conducted through semi-structured interviews with individuals from the selected SMEs. Purposive sampling [28] was used to select participants who held responsibilities in sustainability reporting, financial reporting with responsibilities relevant to sustainability disclosures, regulatory compliance, data management or at the intersection of these areas, with each participant having expertise in emissions data practices within SMEs. The sampling frame was initially defined through collaboration with the advisory firm, which facilitated identification of SME clients actively engaged in preparations for CSRD-aligned sustainability reporting. This partnership enabled targeted outreach to organizations fitting the research criteria across diverse sectors such as retail, consulting, logistics, and healthcare, ensuring a representative mix of contexts for exploring sector-specific and cross-industry challenges. From this sampling frame, key informants within each SME were identified with the firm's assistance, focusing on individuals meeting the aforementioned criteria. To enhance internal validity and reduce bias, we aimed to conduct at least two interviews per organization where possible, allowing within-case comparability and the emergence of deeper insights into emissions data collection, measurement, and reporting practices.

A total of 9 interviews were conducted across 6 distinct SMEs (see Table 1). Interviews lasted up to 1 hour, and guided by a semi-structured format to facilitate in-depth discussions. This approach enabled participants to share their experiences, providing context-rich insights into operational and strategic challenges related to emissions reporting and the use of current systems. The interview questionnaire (see Appendix B) addressed key themes including data availability, technological preparedness, integration of reporting processes, verification mechanisms, and perceived barriers to achieving CSRD alignment. Section 3.2 presents the interview analysis results.

3 Findings

3.1 Normative Emissions Reporting Expectations Under the CSRD

This section presents the findings of the document analysis as an integrative narrative summary. It synthesizes SME regulatory requirements from ESRS 1 and 2 on business conduct and general disclosure stipulations, alongside emissions reporting requirements from ESRS E1. Based on this synthesis, the passage below outlines key, non-exhaustive

Table 1. Interview Participants and Their Affiliated SMEs.

Participant	Role	Responsibilities	SME	Sector
P1	ESG reporting manager	Responsible for ESG reporting	A	Retail
P2	Sustainability advisor	Leads sustainability initiatives	B	Healthcare
P3	Head of CSRD	Leads implementation of CSRD	C	Construction
P4	Sustainability manager	Oversees sustainability initiatives on climate change and waste	C	Construction
P5	Financial & sustainability manager	Leads financial/sustainability reporting and ESG strategic advisory	D	Logistics
P6	Reporting analyst	Preparing internal and external financial reports	D	Logistics
P7	Sustainability advisor	Strategic lead for sustainability	E	Healthcare
P8	Corporate group controller	Financial control, including oversight of CSRD-related processes	E	Healthcare
P9	Facility advisor	Collecting and analyzing building-related emissions data	F	Consulting

normative expectations, highlighted in *italics*, specifying the obligations SMEs must meet under the CSRD for emissions reporting.

To begin with, the CSRD aims to improve ESG reporting by improving transparency, consistency, and accountability across EU member states and sectors. Responding to longstanding inconsistencies, the CSRD aims to ensure that ESG disclosures, particularly emissions reporting under the ESRS E1, are *structured, accurate, reliable, complete, verifiable, and auditable* [13]. One of the directive's core objectives is to enhance comparability and ensure that *sustainability information can provide the level of quality and mandatory assurance* to support its evaluation with the *same level of scrutiny as financial statements* [27,17].

A central principle embedded in the CSRD is the concept of double materiality, compelling companies to report both on how their activities impact people and the planet (impact materiality), and on how environmental and social developments affect their financial performance (financial materiality) [9,6]. Impact materiality encompasses disclosures related to issues such as GHG emissions under the ESRS E1 and contributions to biodiversity loss. Conversely, the financial materiality focuses on how environmental risks might disrupt business operations or revenues. For effective implementation of double materiality, SMEs would have to *gain access to value chain data and develop methodologies to evaluate sustainability risks in a manner compatible with short-term financial reporting cycles (i.e., monthly or quarterly)* [21,9].

A critical requirement of the CSRD, as specified in ESRS E1, is the mandatory reporting of GHG emissions, classified into Scope 1, Scope 2, and Scope 3 emissions [12]. Scope 1 refers to direct emissions from company-controlled sources. Scope 2 includes indirect emissions from purchased electricity. Scope 3 encompasses all other indirect emissions across the value chain. Accurate emissions reporting relies on the use of standardized methodologies and verifiable data sources. For Scope 1 and 2 emissions, data is usually derived from direct measurements, such as fuel consumption and electricity usage records. However, Scope 3 emissions, representing the largest share of a company's carbon footprint, require complex estimation methods such as supplier surveys and lifecycle assessments [31]. SMEs face added difficulties in this area due to siloed data systems, lack of expertise, and limited access to emissions benchmarks [5]. As a result, *ensuring data accuracy and robust estimation methodologies in Scope 3 emissions disclosures* emerges as a critical requirement in regulatory compliance, particularly when SMEs depend on estimates rather than direct measurements [36]. In addition, the *quantification of Scope 3 emissions using verifiable data* can be particularly difficult for organizations that rely on external partners for such estimates [30].

One of the key difficulties SMEs face in implementing the CSRD is ESG data collection and management. Without centralized systems or dedicated sustainability teams, SMEs often collect ESG data through decentralized manual processes involving multiple departments, external consultants, and third-party actors across the broader supply chain. This approach increases the risk of errors and inconsistencies [5] and goes against an important mandate of the CSRD which is the *presentation of sustainability information in a retrievable, comparable, and machine-readable format* [14]. To address these challenges, SMEs are often compelled to invest heavily in integrated sustainability management systems or seek partnerships with larger firms to *improve data harmonization*, exposing them to further costs [1].

Finally, achieving CSRD compliance entails a substantial time commitment, which can detract from the operational focus of SMEs, particularly those with limited resources [3]. While the ESRS are designed to reflect the principle of proportionality for smaller companies, they remain legally binding for in-scope SMEs, including listed entities. These standards aim to balance regulatory expectations with practical capacities of smaller firms, yet still require the establishment of *structured and verifiable reporting processes and the allocation of dedicated resources* to achieve those [10].

3.2 Practical Challenges and Practices of SMEs in Emissions Reporting

This section presents the results of the analysis of interview data from the case study. The interviews were audio-recorded and transcribed verbatim for analysis. We employed thematic content analysis [34], a method well-suited for identifying, organizing, and interpreting patterns of meaning across qualitative datasets. Adopting a bottom-up, inductive approach, we began with an initial round of open coding, conducted manually without a predefined codebook. During this phase, segments of text conveying meaningful insights were highlighted and assigned descriptive, in vivo codes, allowing salient concepts to emerge directly from the data. Following this exploratory analysis, recurring and conceptually significant codes were identified, refined, and consolidated into a preliminary structured codebook (see Appendix C). This codebook functioned as

an analytical scaffold to support consistency in the subsequent stages of analysis. Next, a second, more systematic round of coding was performed: all transcripts were revisited and recoded using the structured codebook. During this phase, code refinements were made to reduce redundancy, clarify code definitions, and ensure consistent application across the dataset. To maintain analytical parsimony, only codes mentioned by at least three interviewees (n>33%) were retained for the final analysis. These retained codes were then grouped into higher-order themes, each representing a distinct category of challenges SMEs face in the collection and reporting of emissions-related data. These themes were not imposed a priori but rather inductively derived from the coded data through constant comparison and interpretive synthesis.

The full set of themes, codes, and supporting quotations is presented in Appendix D. Due to space constraints and in the interest of conciseness, a summary of the thematic findings is presented in Table 2, which is structured in accordance with the guidelines of Miles et al. [23] for the systematic presentation of qualitative data derived from interviews. Specifically, the first column identifies the emergent theme; the second lists the associated codes; the third provides representative, abbreviated quotation excerpts from interview transcripts offering a condensed yet interpretable view of the challenges SMEs encounter in emissions data reporting; the fourth column reports the participant identifiers for each excerpt. Overall, our analysis revealed four overarching themes: *(1) Fragmented and manual data acquisition*, *(2) Low quality of emissions data*, *(3) Complexity of Scope 3 data*, and *(4) Compliance overload*. Each theme consolidates a set of underlying codes and captures recurring, practice-oriented challenges that SMEs experience as they prepare to comply with the CSRD.

The first theme, fragmented and manual data acquisition, highlights that current emissions data reporting practices among SMEs are largely ad hoc, labor-intensive, and prone to error. Across multiple cases, participants described a persistent reliance on Excel spreadsheets and non-integrated tools to manage emissions data. Inputs are typically sourced from a wide range of disconnected systems, including energy invoices, HR surveys, and operational logs, and must be manually compiled. This patchwork process often requires repetitive copy-pasting and manual consolidation, which introduces inefficiencies and increases the likelihood of errors. Moreover, the absence of automation and real-time validation mechanisms leads to common mistakes, such as decimal misplacements or omitted data entries. The infrequency of updates, often limited to annual cycles, further undermines the accuracy and responsiveness of emissions reporting.

Another key theme emerging from the analysis concerns the systemic challenges SMEs face in accounting for Scope 3 emissions, a central requirement under the CSRD. Interviewees reported limited access to emissions data from suppliers, which often compels SMEs to rely on spend-based estimation methods which approximate Scope 3 emissions by multiplying expenditures by average emissions per monetary unit. While practical, these methods were widely perceived as imprecise and insufficiently representative of actual environmental impact. Compounding this issue is the lack of robust digital tools to support Scope 3 reporting, in contrast to the more structured solutions available for Scope 1 and 2 emissions. As a result, SMEs resort to manual workarounds in spreadsheets, further increasing reporting complexity. Participants also raised growing concerns about compliance fatigue, noting that the reporting burden often falls on

Table 2. Summary of Key Themes, Codes, Illustrative Quotes, and Contributing Participants.

Theme	Code	Illustrative Quotes (Abbreviated)	Participant
Fragmented and manual data acquisition	Reliance on Excel	*We do a lot in Excel...* *Still waiting for a global system...*	1,2,4,6,9
	Manual data input	*Colleagues enter data manually...* *We paste everything into the tool by hand...*	1,2,3,4,8
	Data from scattered sources	*Data comes from emails, invoices, surveys...* *We glue things together manually...*	1,2,3,5,6,9
Low quality of emissions data	Incomplete supplier data	*Few suppliers provide CO_2 data...* *Most have no idea about their emissions...*	1,2,3,7,9
	Human entry errors and typos	*Typos turn millions into billions...* *Wrong decimals, missed rows...*	1,4,6,8
	Reporting infrequency	*Annual water usage only...* *No month-to-month visibility...*	2,7,3,9
Complexity of Scope 3 data	Spend-based estimates	*We estimate based on spend...* *No unit-level CO_2 data...*	1,2,3,4,5,7,9
	Lack of tool support for Scope 3	*No Scope 3 support in our tools...* *Done manually in Excel...*	1,2,3,4,7,9
Compliance overload	Delegation to finance	*Finance took over sustainability...* *Accountants now handle reporting...*	2,5,8,9
	Compliance vs. actual impact	*Less time for real projects...* *Reporting eats all the time...*	2,4,7,9
	Declining motivation	*We're just reporting, not doing sustainability...* *Front-runners get no reward...*	2,6,7,8

finance departments, sidelining operational teams and reducing overall organizational engagement in sustainability efforts.

3.3 Feature Recommendations

This section presents the feature recommendations (see Table 3) developed to address discrepancies between CSRD regulatory demands and the practical challenges SMEs face during implementation. Through an iterative process, the normative expectations identified in Section 3.1 were juxtaposed with the analyzed SME interview data presented in Section 3.2 to identify instances where regulatory requirements influenced, conflicted with, or were unmet by SME practices. This mapping was conducted by comparing the language and intent of these expectations with detailed accounts of SME workflows and challenges, aiming to pinpoint specific areas where SMEs struggled to comply with these requirements. This cross-referencing informed the development of system-level features aimed at supporting SMEs in achieving CSRD compliance, with a specific focus on emissions reporting. Each feature is presented in Table 3 as a structured recommendation, detailing the system's required capability, explaining its operation through specific actions, and outlining complementary capabilities that support

the primary one. Presenting these features as capabilities rather than functionalities is intentional since capabilities emphasize what the system enables SMEs to achieve, without prescribing specific technical operations that would require detailed knowledge of each organization. For example, the automated data integration capability mentioned below consolidates dispersed emissions data while allowing customization to meet each SME's specific needs. Grounded in empirical evidence, each capability is therefore adaptable, scalable, and actionable, ensuring system features are both technically meaningful and flexible enough to accommodate the diverse constraints of different SMEs.

Table 3: Feature Recommendations for CSRD-Aligned SME Reporting.

Normative Expectation	**SME Challenge**	**Feature Recommendation**
Data collection process is expected to be structured and verifiable to support accurate, complete, and auditable emissions disclosures	Reliance on manual data input and fragmented sources (e.g., Excel, emails)	The system enables seamless retrieval and consolidation of emissions-related data from diverse external platforms via standardized APIs, to reduce manual effort and improve traceability
Emissions data is expected to meet standards of quality, accuracy, auditability, and assurance to support credible reporting	Introduction of human entry errors, typos, and inconsistent formatting	The system ensures high-quality emissions data by applying real-time validation rules that detect anomalies, missing values, and formatting inconsistencies
Scope 3 emissions are expected to be quantified using consistent methodologies and supported by traceable data sources	Lack of supplier chain data and reliance on spend-based estimates	The system supports flexible Scope 3 emissions estimation using supplier-specific inputs, activity-based data, and industry benchmarks, complemented by supplier engagement tools allowing the collection, integration, and validation of emissions data
Data updates are expected to occur regularly and align with the financial reporting cycle to ensure timeliness and consistency	Collection of data occurs infrequently, mostly on an annual basis, through surveys	The system allows emissions data to be captured and analyzed at monthly, quarterly, and annual intervals, enabling timely insights and alignment with financial cycles
Data management processes are expected to be consistent, standardized, and well-documented, supported by dedicated resources	Operational strain on finance staff due to the lack of dedicated ESG teams	The system facilitates distributed data management by enabling granular role assignments (e.g., data contributors, reviewers, auditors, financial controllers), promoting secure and efficient collaboration

Normative Expectation	SME Challenge	Feature Recommendation
Data reporting is expected to achieve a level of structure and verifiability comparable to financial reporting	Increasing effort on compliance with reduced perceived impact, coupled with reporting fatigue	The system provides structured reporting templates aligned with mandated disclosure areas, and interactive dashboards that visualize emissions trends and sustainability metrics
Reports are expected to be machine-readable to enable seamless data exchange across departments and organizations	Excessive reliance on manual reporting and absence of digital outputs	The system supports machine-readable exports (e.g., XBRL, XML, CSV), enabling automated processing and interoperability with external reporting platforms

Building on these recommendations, effective systems should directly respond to the specific reporting challenges SMEs face. For instance, to meet the CSRD's emphasis on structured and verifiable data collection, SMEs would benefit from reporting systems that enable automated data integration via APIs with relevant external platforms. This directly addresses the prevalent reliance on manual data entry methods such as the use of Excel spreadsheets and fragmented email workflows and surveys, reported by participants. By eliminating repetitive data entry and enabling real-time synchronization, such systems can significantly improve efficiency and reduce input errors. Additionally, to ensure data quality, auditability, and assurance in emissions reporting, these systems should include robust data validation layers that automatically detect and flag incomplete, inconsistent, or erroneous entries. This helps mitigate common issues such as typos, unit mismatches, and formatting inconsistencies. In addition to data integration and quality assurance, several other CSRD expectations call for tailored system capabilities. One critical area is the quantification of Scope 3 emissions, which many SMEs find particularly challenging due to limited access to supplier-specific data and an over-reliance on spend-based estimation methods. A recommended system feature is a modular Scope 3 estimation engine supporting hybrid calculation methods, accommodating activity-based data, supplier inputs, and industry averages. This should be complemented by a supplier engagement portal to facilitate third-party emissions data collection and validation. To comply with the CSRD's requirements for timely and frequent data updates, systems must allow SMEs to configure the temporal granularity of data collection, enabling transitions from annual surveys to monthly or quarterly reporting intervals. Furthermore, role-based access control and collaboration functionalities are essential to prevent operational overload, particularly in finance teams, and to promote secure, cross-functional engagement in ESG data management. By integrating these capabilities, SMEs can implement reporting systems that not only streamline compliance workflows but also reduce reporting fatigue and enhance the strategic value of sustainability reporting within their organizations.

4 Limitations

This section outlines key limitations that may have influenced our results. *First*, this study focuses solely on ESRS E1 for emissions reporting. E1 was prioritized for its

central role in GHG reporting, while other dimensions of the CSRD (social, governance) and other ESRS standards (e.g., biodiversity) were excluded, as they involve different metrics. As a result, challenges specific to these areas are not captured here. Future research should address these additional areas for a more comprehensive view of SME reporting under the CSRD. *Second*, the empirical data are drawn from 9 semi-structured interviews across 6 SMEs in the Netherlands. While this sample enabled a context-sensitive exploration of emissions data practices and challenges, its size remains limited. The SMEs cover a select range of industries and are primarily located in the Netherlands, which may restrict the transferability of insights to other sectors or geographic contexts. In addition, one planned follow-up interview could not be conducted due to participant scheduling constraints. We therefore stress the importance of independent evaluations and larger multi-country studies with more diverse samples to further validate and generalize these findings. *Third*, the document analysis relied predominantly on grey literature. While such sources provide timely and relevant regulatory insights, their findings should be interpreted with some caution. Moreover, the normative expectations identified from this analysis are inherently non-exhaustive, as they reflect the insights available in the publicly accessible documents retrieved for this study and may not capture the full range of regulatory interpretations. However, we applied a structured document retrieval approach, and the identified expectations serve as a basis for comparing real-world practices with the intent of formal legal and policy requirements as set forth in official implementation materials. *Fourth*, the proposed feature recommendations are presented at a high level and do not include the conditions or constraints needed to implement them. While they draw on both theory and practice to address compliance challenges and translate them into operational pathways to improve emissions reporting, they must be further refined, specified, and empirically validated before guiding the development of concrete system specifications.

5 Conclusion

At this stage, we can return to our stated research questions. The first, concerning the key challenges SMEs face in preparing for CSRD-compliant emissions reporting, was addressed through an empirical, inductive approach. We conducted a case study using semi-structured interviews with SME representatives to capture firsthand experiences, operational challenges, and organizational practices in emissions data management. Recognizing that empirical insights alone may not fully capture the demands placed on SMEs in terms of CSRD compliance, we complemented this perspective with a top-down (deductive) analysis of regulatory expectations. The integration of these two perspectives revealed recurring barriers to digitally enabled emissions reporting practices, including reliance on manual data entry, limited supplier data access, fragmented workflows, difficulties estimating Scope 3 emissions, and reporting cadence. To address the second research question, on how digital reporting systems could support SMEs, we translated the previously identified insights into a set of feature recommendations. These recommendations are intended to guide the design and adaptation of digital systems in a way that reconciles regulatory requirements and addresses gaps in SME practices. They provide practical solutions, expressed as system capabilities, to

support compliant emissions reporting. It is important to note that the proposed features are tailored to the operational realities of SMEs rather than large organizations. Each capability in the feature recommendations is designed to address concrete challenges identified in the study (fragmented data sources, manual reporting workflows, limited access to supplier emissions data, etc.,) without making presuppositions regarding the presence of enterprise-level infrastructure or dedicated ESG teams. For example, automated data integration helps SMEs move beyond spreadsheets and emails by consolidating data from multiple sources automatically, while hybrid Scope 3 modeling and estimation allows SMEs to produce reliable emissions estimates even when supplier-specific data is incomplete or unavailable. Role-based access control and configurable reporting cadence enable lightweight collaboration and granular reporting cycles, best suited to SME needs. Although grounded in empirical evidence of SMEs' practices, these features remain non-prescriptive. Future research can extend the investigation to additional ESG dimensions for a more comprehensive understanding of SME reporting under the CSRD and translate the identified features into formal system requirements.

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